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Impact of shale oil and shale gas on underground water

Summary

The present document was prepared in response to recommendations issued by the Energy Committee at its tenth session, to study the impact of shale oil and shale gas (unconventional resources) on underground water. It provides a critical analysis on the environmental effects of shale development on underground water, water availability and the environment in general, and how these effects might impact Arab countries.

The document also highlights enabling factors that policymakers should assess before developing unconventional resources.

CONTENTS

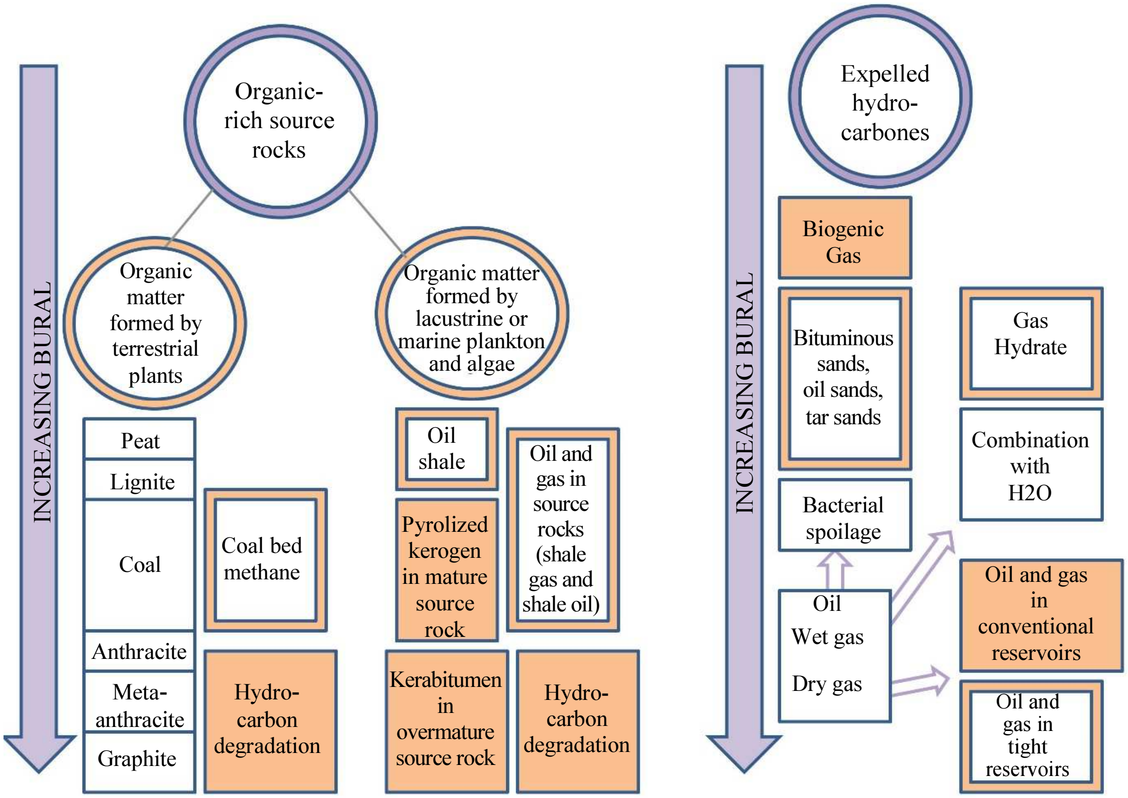
Introduction

1. Although unconventional resources are large, they are not widely exploited. The industry is still in the learning stage regarding many resources outside North America, with each unconventional resource posing distinctive challenges. It has not yet been demonstrated that technologies well adapted to existing production areas can unlock resource potential in other regions.

2. Unconventional resources exist in Arab countries, some of which have limited conventional resources (Jordan and Tunisia) and others that have bountiful conventional hydrocarbon resources (Algeria, Egypt, Libya, Oman and Saudi Arabia). Although the shale oil and gas revolution in the United States of America has encouraged policymakers in many Arab countries to tap into their unconventional resources, the environment poses complex challenges in terms of geology, lack of advanced technologies, water availability and public acceptance.

3. Fracking techniques used to extract shale oil and gas trapped in rocks are seen as a potential pollutant of drinking water, and are thus highly controversial. Moreover, such environmental impacts and associated operations are far from being compensated by benefits from job creation, tax revenue and low delivery costs to local communities.

Figure 1. Unlocking unconventional resources



Source: www.sgs.com/en/oil-gas/upstream/unconventional-resources.

I. OVERVIEW OF SHALE OIL AND GAS RESOURCES AND DEVELOPMENT

A. DEFINITION

4. Unconventional resources exist in petroleum accumulations that are pervasive throughout a large area, and are not significantly affected by hydrodynamic influences. These include coalbed methane (CBM), basin-centred gas, shale gas, gas hydrate, natural bitumen (tar sands) and oil shale deposits. The unconventional deposits usually require specialized extraction technology (e.g., dewatering of CBM, massive fracturing programmes for shale oil and gas, steam and/or solvents to mobilize bitumen for in-situ recovery and, in some cases, mining activities).[1] The unconventional resources discussed in the present document include shale oil and shale gas, tight oil and gas and CBM. Ultra-heavy oil, oil sands, coal to liquid, offshore and gas hydrates, among others, will not be covered in detail.

B. HISTORICAL OVERVIEW

5. Shale oil was discovered in the tenth century, according to written records demonstrating the extraction of oil from shale rocks back then.[2] In 1855, Mormon settlers founded the first shale oil operation in the Rocky Mountains in western United States. In 1825, in Fredonia, New York, the first shale gas extraction process was carried out. However, the industrial production of shale technology did not commence for another 150 years.[3]

6. Canada and the United States are pioneers in shale technology, allowing them to increase their oil and gas production. Their success has encouraged other countries to accelerate their efforts and explore their resources, mainly Argentina, China and the United Kingdom. Some Arab countries have also started to consider exploring their unconventional resources, namely Algeria, Jordan, Morocco, Saudi Arabia and Tunisia.

C. POTENTIAL OF SHALE OIL AND SHALE GAS RESOURCES

7. The shale oil and gas resource base is highly uncertain, as assessments have only recently been conducted. Most studies suggest a wide range of recoverable resources, but they are still relatively poorly known.

8. Global estimates do not cover the same regions, do not use the same definitions, and are based on a number of different methodologies and assumptions, which may explain estimate variations. The present document uses the latest assessment from the EIA, released in September 2013, which has been revised based on country reports published later by the EIA and other research institutions.

9. Based on latest estimates, two-thirds of the assessed, technically recoverable shale oil resource is concentrated in the following eight countries: Argentina, Australia, Chad, China, Libya, the Russian Federation, the United Arab Emirates and the United States. The top 10 countries (figure 4) account for about three-quarters of the currently assessed, technically recoverable shale oil resources of the world.

10. Two-thirds of the assessed, technically recoverable shale gas resource is concentrated in the following seven countries: Algeria, Argentina, Australia, Canada, China, Mexico, Saudi Arabia and the United States. As shown in figure 3, the top 10 countries account for over 80 per cent of the currently assessed, technically recoverable shale gas resources of the world.

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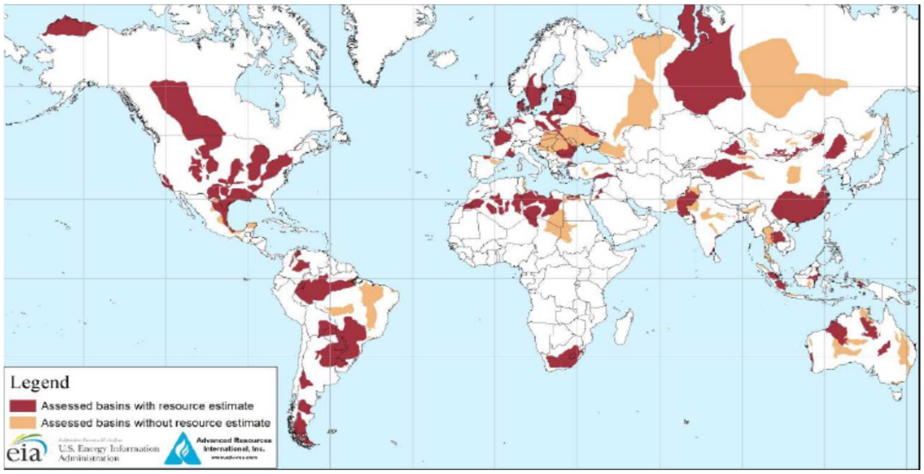
[1] See www.spe.org/industry/docs/PRMS_Development_Process_Slides.pdf.

[2] See www.redleafinc.com/history-of-oil-shale.

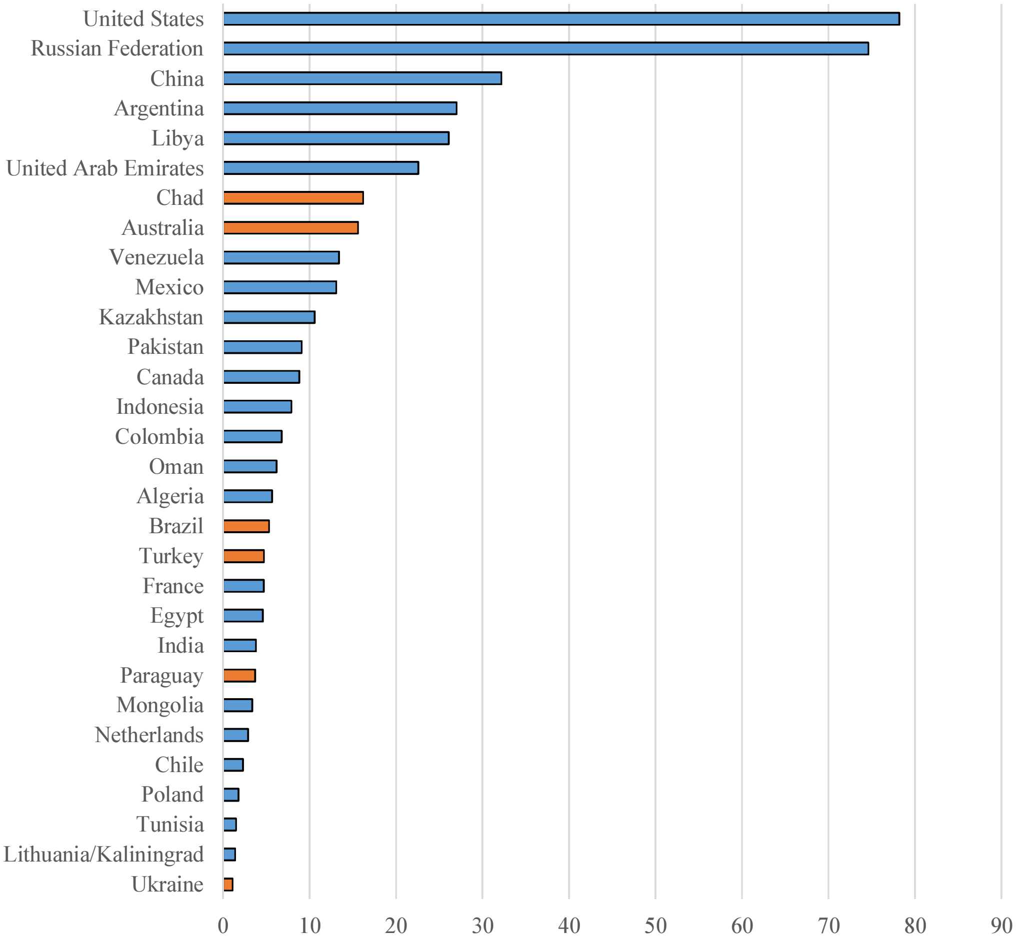
[3] See http://oilpro.com/post/645/the-history-of-shale-in-the-us.

Figure 2. Map of basins with assessed shale oil and shale gas formations



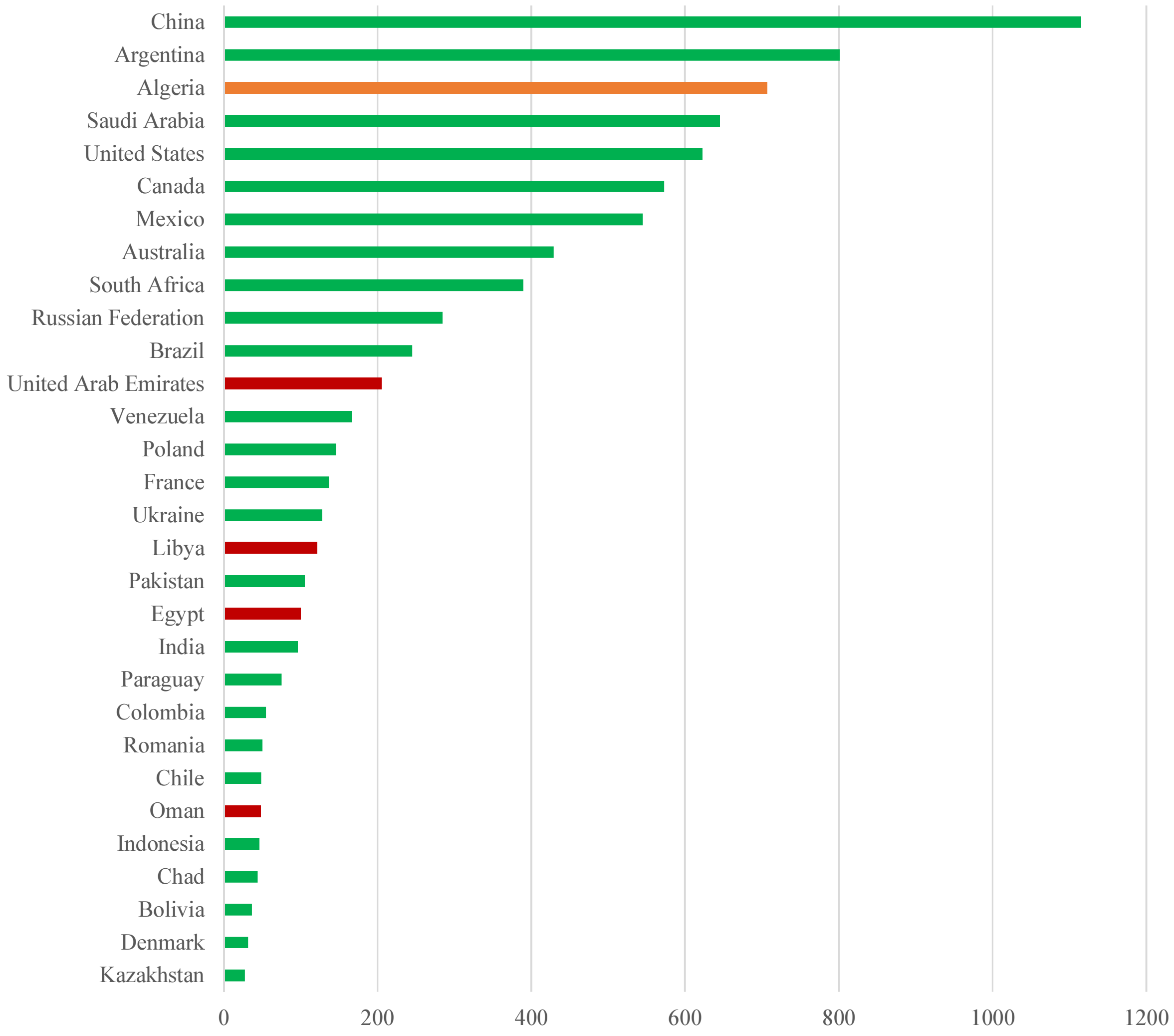
Source: https://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf.

Figure 3. Shale oil resources: top 30 countries
(*Billion barrels*)



Source: www.eia.gov/analysis/studies/worldshalegas.

Figure 4. Shale gas resources: top 30 countries
(*Trillion cubic feet*)



Source: www.eia.gov/analysis/studies/worldshalegas.

D. RECENT GLOBAL AND REGIONAL DEVELOPMENTS

11. Various countries have recognized the importance of exploring shale oil and gas within their territories, such as Argentina, China, Poland and the United Kingdom. However, outside the United States, no major results have been achieved, either because countries are still struggling to establish an enabling environment or secure political and public acceptance for such unconventional resources.

12. Even the United States, which was able to unlock its shale oil and gas resources and move from an importing country to a potential exporting country, is now facing economic challenges due to the decline in oil prices since June 2014 that has affected its production and drilling activities. Only the major fields (Marcellus and Barnett) are able to compete and many operating companies are facing financial deficit. This raises questions about the sustainability of shale production in the United States, and the extent to which it could be replicated in other countries.

13. In the Arab region, Algeria has adopted a new fiscal regime to encourage foreign investment in its shale oil and gas resources. However, the country has faced public demonstrations on the possible impact of such development on the environment and underground water.

14. On 17 December 2014, Egypt signed its first hydraulic fracturing contract to drill up to 14,000 feet. Oil shale was found in the Western Desert and in Sinai. Some reports indicated shale gas potential, but its development is still not technically and economically feasible.

15. Jordan has significant deposits of shale oil and gas. The Minister of Energy and Mineral Resources said that the country was finalizing the financing of a $2.2 billion power plant running on shale oil, with a capacity of 470 megawatts, which was expected to begin its operations by 2019.[4]

16. Saudi Arabia stepped up its unconventional resources programme in 2011, and is focusing on the northwest of the country, while international companies are exploring Rub' el Khali.[5] The kingdom could face water availability challenges for hydraulic fracking, but is still aiming to develop the industry to satisfy growing electricity demand.

17. Tunisia is facing a declining gas production trend, which can be reversed by exploring shale oil and gas reserves. It is conducting a study of future gas sources to help the Government make the right strategic choices for the industry.[6]

18. The United Arab Emirates has also been involved in the seismic exploration of unconventional resources. The Abu Dhabi National Oil Company is planning to drill deep into its shale gas reserves (7,000-14,000 feet) to test economic feasibility.[7]

19. Overall, shale oil and gas resource development outside North America remains a challenge and requires a combination of different enabling factors (above and below ground).

II. WATER USAGE IN SHALE GAS AND OIL EXTRACTION

20. The process of extracting shale gas and oil is quite similar to that of conventional resources. However, there are certain differences in terms of the extensive number of wells to be drilled in a shorter duration (2-4 months), compared with the process used in drilling a conventional oil well (up to 1 year). In addition, intense volumes of water are used during the fracking process to extract hydrocarbons.

21. Fracking is not a new process; it is a well-established technology used in more than 1 million wells over 60 years. Creating cracks inside the shale rocks allows the oil and gas to flow smoothly into the inserted wellbore casing and extraction system, which provides a higher fluid flow rate from inside the rocks (figure 5).

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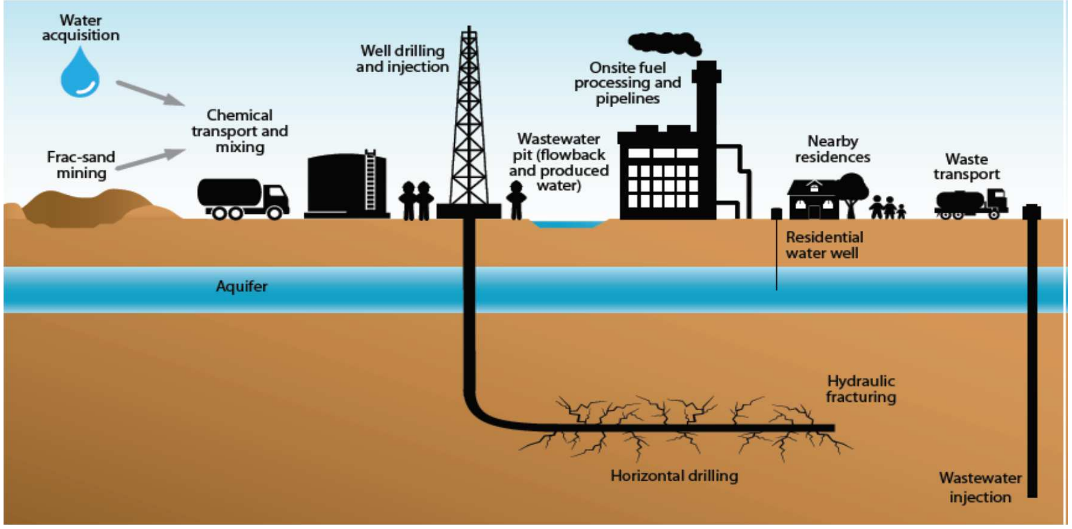
[4] See www.jordantimes.com/news/local/construction-first-shale-power-plant-start-june.

[5] See www.regesterlarkin.com/wp-content/uploads/RL_Shale_Report_February_20141.pdf.

[6] See http://blogs.worldbank.org/arabvoices/tunisia-faces-tough-strategic-choices-demand-energy-begins-outstrip-supply.

[7] See www.eia.gov/analysis/studies/worldshalegas/pdf/UAE_2014.pdf.

Figure 5. Illustration of typical steps of unconventional oil and gas development

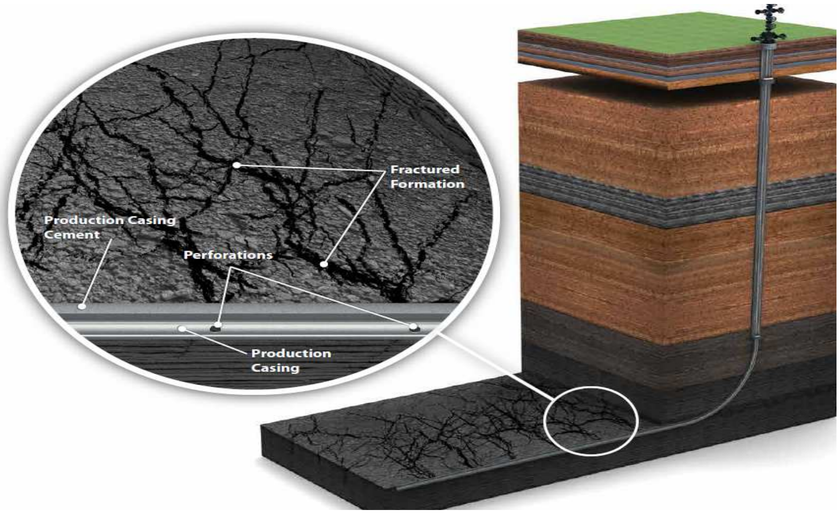


Source: www.ucsusa.org/sites/default/files/attach/2015/07/ucs-managing-risks-unconventional-oil-gas-development-2015.pdf.

A. HYDRAULIC FRACTURING PROCESS

22. Hydraulic fracturing is the process through which rock structures are broken up to enable oil or gas to flow out easily. It allows extraction of hydrocarbons from deep geological formations (3,000 to 16,000 feet) with low permeability, by giving hydrocarbons the necessary impetus to reach the well.[8] Hydraulic fracturing has been conducted for several decades in vertical and horizontal wells. The scale and number of wells drilled, and the related technology have advanced rapidly over the last few years and have allowed an increase in oil and natural gas extraction. This expansion has opened up the development of many oil and gas resources previously thought inaccessible.

Figure 6. Shale rock fracking process before water injection



Source: https://fracfocus.org/water-protection/hydraulic-fracturing-usage.

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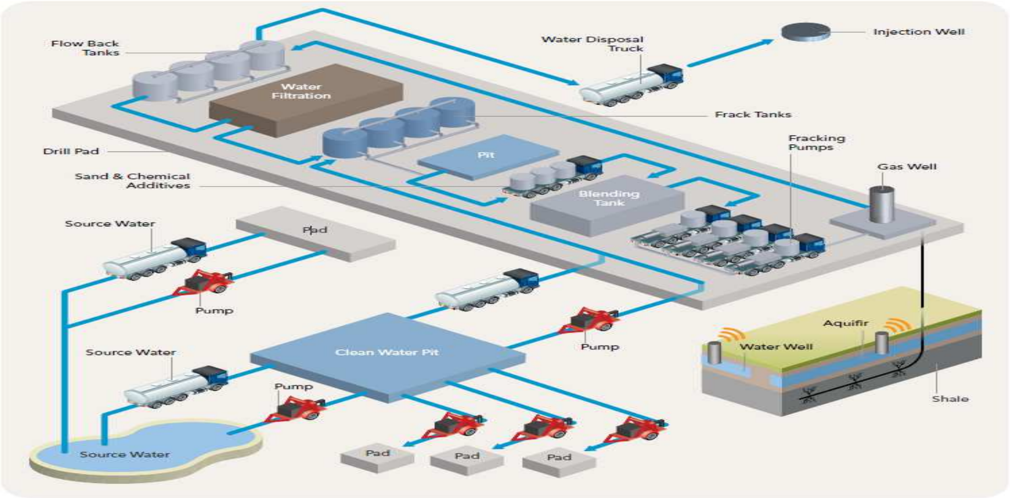
[8] See https://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf.

B. WATER USAGE IN EXTRACTION PROCESSES

23. Fresh water is used during the fracking process. It requires carrying a mixture of sand and other chemicals inside the well cracks to extract oil and gas from shale rocks. The fresh water is usually obtained from nearby rivers, lakes, manmade reservoirs and municipal supplies.

24. Water is pumped from the source and mixed with sand and chemicals for use in the fracking process. After the extraction of the oil and gas particles from underground shale basins, water is pumped back up to the surface and saved in a flow back tank where the water is filtered to be reused again. One of the main obstacles facing shale oil and gas extraction is the considerable amount of water used during the fracking process. Figure 8 shows the large volumes of water in cubic metres per well used in the big shale wells in the United States.

Figure 7. Process of providing water for shale oil and gas extraction



Source: http://oilandgas.xylem.com/en-us/industries/oilandgas/Documents/WhitePapers/Water%20Use%20Oil%20Gas.pdf.

25. The amount of water needed varies according to the depth of a well. On average, the amount of water used ranges between 670 cubic metres and 19,305 cubic metres per well. The amount of water used per well has increased due to horizontal drilling technology. The median water usage for hydraulic fracturing is estimated at 5.6 million litres.[9]

26. This extensive use of water could be challenging in places experiencing water scarcity. This is the case in Arab countries with shale oil and gas resources.

C. WATER ACQUISITION

27. The water used in fracking comes mainly from fresh surface water and underground water. However, wastewater is used in the process to reduce fresh water consumption. Figure 9 shows the breakdown of different types of water used in the fracking process in two of the biggest shale oil and gas basins in the United States (Marcellus Shale Susquehanna River and Barnett Shale in Texas).[10]

28. As shown in figure 9, most of the water used in the fracking process comes from surface water. Around 90 per cent of the produced or flowback water is reused in the next cycle of hydraulic fracking in the Marcellus shale play, thus saving fresh water.

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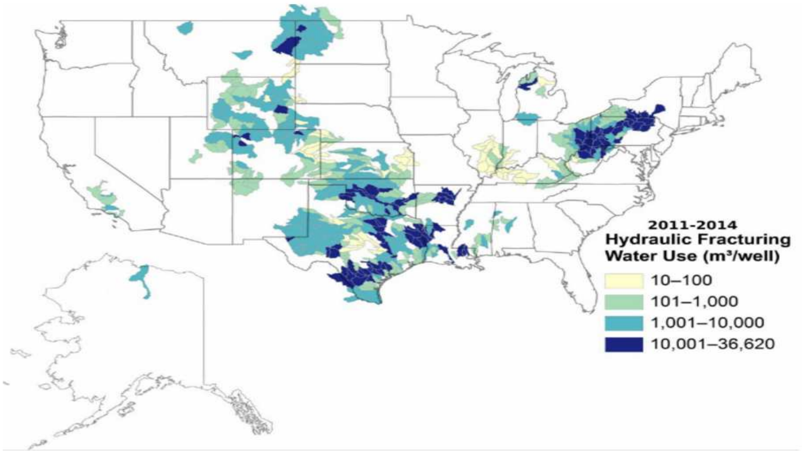
[9] See www.climatecentral.org/news/fracking-water-use-skyrockets-19177.

[10] Ibid.

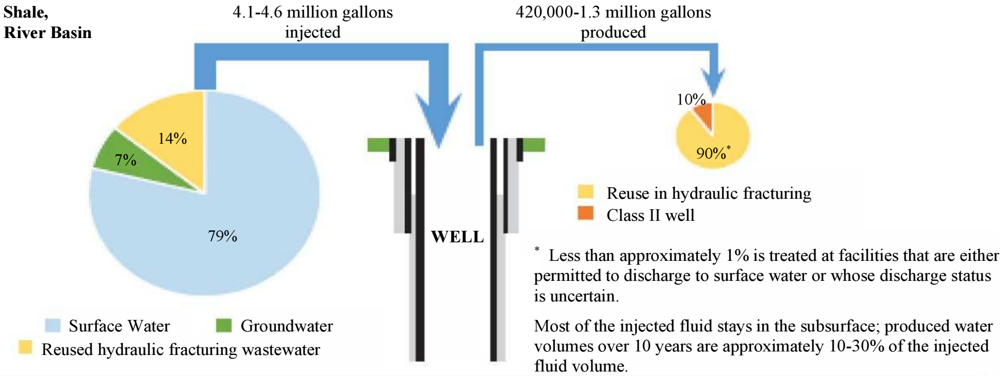
Figure 8. Amount of water used in different oil and gas shale basin in the United States



Source: http://www.climatecentral.org/news/fracking-water-use-skyrockets-19177.

Figure 9. Water budgets illustrative of hydraulic fracturing water management practices in the Marcellus Shale in the Susquehanna River Basin (2008-2013) and the Barnett Shale in Texas between (2011-2013)

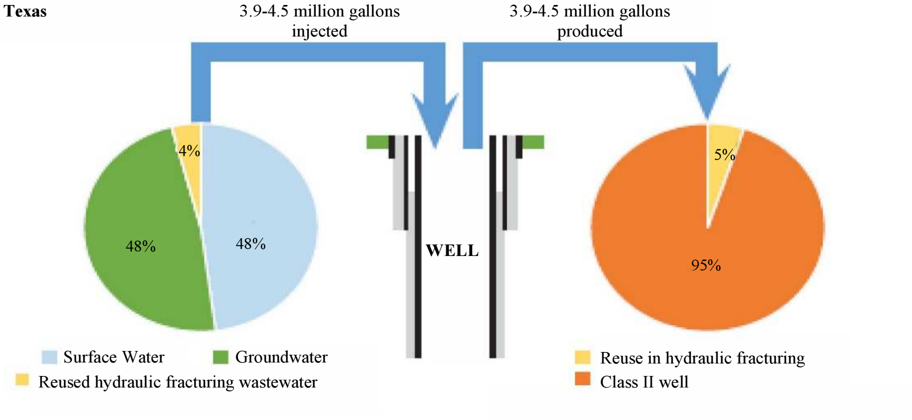
(a) Marcellus Shale, Susquehanna River Basin



* Less than approximately 1% is treated at facilities that are either permitted to discharge to surface water or whose discharge status is uncertain.

Most of the injected fluid stays in the subsurface; produced water volumes over 10 years are approximately 10-30% of the injected fluid volume.

(b) Barnett Shale, Texas



Produced water volumes over three years can be approximately the same as the injected fluid volume.

Source: https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

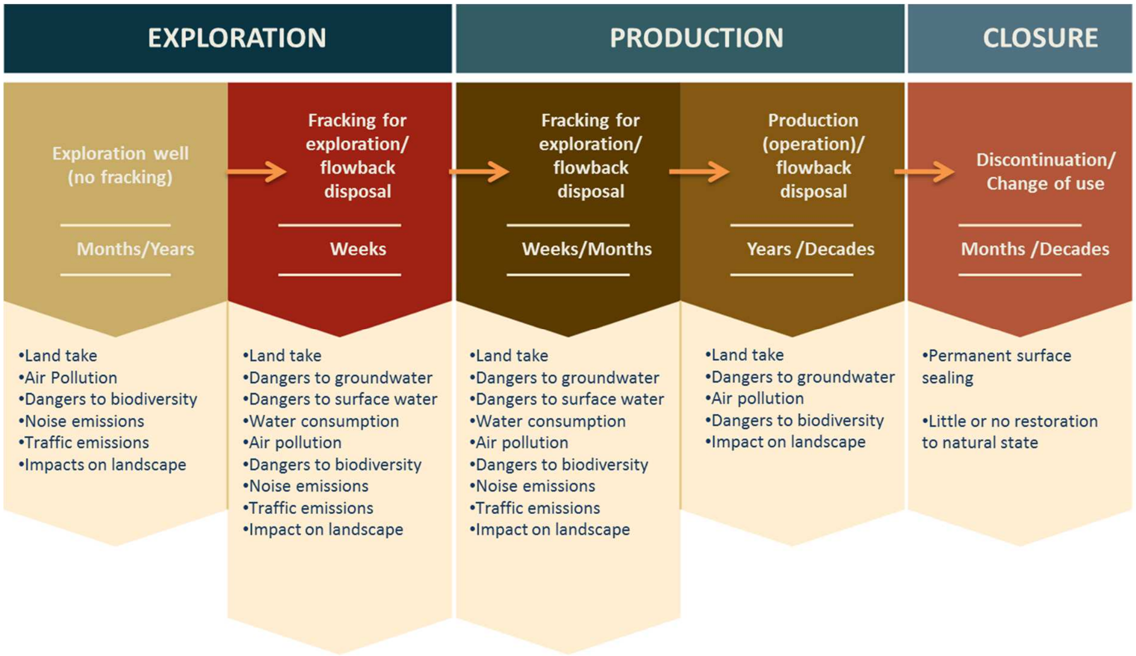
III. ENVIRONMENTAL RISKS OF SHALE OIL AND GAS DEVELOPMENT

29. According to a study by the European Parliament, the activities related to unconventional oil and gas production lead to some unavoidable environmental impacts, ranging from land occupation (due to drilling pads, trucks, equipment), ground water contamination, air pollution, and accidents that can be harmful to human health and the environment.[11]

30. Figure 10 provides a general overview of the impact of fracking on the environment throughout the value chain, and after the closure of shale oil and gas wells.

31. The impact of fracking on the environment is still highly controversial and dependent on local conditions, water availability and technology use, among other factors. The impact on underground water has been subject to different studies, especially in the United States, where extensive shale gas and oil drilling and production activities are taking place and have changed the natural landscape.

Figure 10. Impact of fracking on the environment



Source:www.umweltrat.de/SharedDocs/Downloads/EN/04_Statements/2012_2016/2013_09_Statement_18_Fracking_for_Shale_Gas_Production.pdf?__blob=publicationFile.

IMPACT ON UNDERGROUND WATER

32. Hydraulic fracturing of a single well has a low impact on drinking water, because of the moderate volume of water needed. However, if multiple oil and gas production wells are located within a specific area, the impact of hydraulic fracturing on underground drinking water increases considerably. Moreover, the biggest impact of increased fracking activities occurs in areas facing water scarcity and drought. For instance, recent statistics show that the groundwater level has dropped from 31 metres to 61 meters in Texas, owing to an increase in water fracking activities since 2009. Other studies conducted by the United States Environmental Protection Agency (EPA) show that hydraulic fracturing withdrawal has affected surface water resources in the Marcellus shale basin.

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[11] See https://europeecologie.eu/IMG/pdf/shale-gas-pe-464-425-final.pdf.

33. However, few studies have put forward concrete data on the impact of hydraulic fracking on undergrownd water and water availability. A recent study, initiated by the United States Congress, was conducted following increasing public concern about the potential impact on drinking water from hydraulic fracturing at shale oil and gas production wells and facilities. The study was conducted by EPA to study the relationship between hydraulic oil and gas fracturing and drinking water in the United States.

34. The results of the study indicate that a reduction in local drinking water has occured in zones with amplified hydraulic fracturing activity. In 2011, for example, drinking water wells in an area overlying the Haynesville Shale ran out of water due to higher than normal groundwater withdrawals and drought.[12] Water withdrawals for hydraulic fracturing contributed to these conditions, along with other water uses and a lack of precipitation. Groundwater impacts have also been reported in Texas.

35. In contrast, studies in the Upper Colorado and Susquehanna River basins found slight effects on drinking water resources from hydraulic fracturing. In the Upper Colorado River Basin, EPA found that high-quality water produced from oil and gas wells in the Piceance tight gas sands provided nearly all of the water for hydraulic fracturing in the study area.[13] Due to this high reuse rate, EPA did not identify any locations in the study area where hydraulic fracturing contributed to high water use locally.

36. In the Susquehanna River Basin, multiple studies highlight the potential impact of hydraulic fracturing on surface water resources in the Marcellus Shale. Evidence suggests, however, that current water management strategies, including passby flows and reuse of hydraulic fracturing wastewater, help protect streams from depletion caused by hydraulic fracturing water withdrawals.[14]

37. In 2014, researchers started focusing on using carbon dioxide to replace water in fracking operations, injected alongside sand and chemicals. General Electric and Statoil have forged a $10 billion partnership to explore the possibility of using this technique. The aim is to collect carbon dioxide at the wellhead, recycle it and then use it to frack again. Frac Master in Canada tested this technique in the 1990s, but the company went bankrupt. Many operators do not implement this new mechanism because of economic considerations.[15] In this respect, IEA has proposed some “Golden Rules” for the development of shale oil/gas resources. The rules consider reducing freshwater use by improving operational efficiency; and reusing or recycling water wherever practicable. It also advocates the safe storage and disposal of wastewater, minimizing the use of chemical additives, and promoting the development and use of more environmentally benign alternatives.[16]

38. Regarding the impact of hydraulic fracking on Arab countries with relatively high shale oil and gas resources, the issue of water scarcity would require further consideration to examine the opportunity of developing such unconventioal resources, bearing in mind the water-energy nexus at the policy and operational levels.

39. In Arab countries, water and energy demand are relatively high compared with the global average. Arab countries also suffer from water scarcity. In the MENA region, water shortages are projected to increase by 43 cubic kilometres per year between the periods 2001-2010 and 2041-2050, even under the most positive climate scenarios. The below table displays the projected list of the top 33 water-stressed countries in 2040; five of the eight countries with the highest stress level are ESCWA members.

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[12] See www.dnr.louisiana.gov/assets/docs/conservation/groundwater/12.Final.GW.Report.pdf.

[13] See www.epa.gov/sites/production/files/2015-11/documents/algal-risk-assessment-strategic-plan-2015.pdf.

[14] A passby flow is a prescribed, low-streamflow threshold below which water withdrawals are not allowed.

[15] See http://oilprice.com/Energy/Energy-General/Water-less-Fracking-Could-Be-Industry-Game-Changer.html.

[16] See www.iea.org/media/weowebsite/2012/goldenrules/InternationalPressCoverage_GoldenRulesforaGoldenAgeofGas.pdf.

TOP 33 WATER-STRESSED COUNTRIES GLOBALLY BY 2040

Rank	Name	Score (all sectors)
1	Bahrain	5.00
1	Kuwait	5.00
1	Qatar	5.00
1	San Marino	5.00
1	Singapore	5.00
1	United Arab Emirates	5.00
1	Palestine	5.00
8	Israel	5.00
9	Saudi Arabia	4.99
10	Oman	4.97
11	Lebanon	4.97
12	Kyrgyzstan	4.93
13	Iran	4.91
14	Jordan	4.86
15	Libya	4.77
16	Yemen	4.74
17	Macedonia	4.70
18	Azerbaijan	4.69
19	Morocco	4.68
20	Kazakhstan	4.66
21	Iraq	4.66
22	Armenia	4.60
23	Pakistan	4.48
24	Chile	4.45
25	Syrian Arab Republic	4.44
26	Turkmenistan	4.30
27	Turkey	4.27
28	Greece	4.23
29	Uzbekistan	4.19
30	Algeria	4.17
31	Afghanistan	4.12
32	Spain	4.07
33	Tunisia	4.06

Source: www.wri.org/blog/2015/08/ranking-world%E2%80%99s-most-water-stressed-countries-2040.

Note: “5.00” is the highest stress score possible.

IV. ABOVE GROUND RISKS AND ENABLERS

40. For the successful development of shale oil and gas resources, not only below ground factors should be studied. Other important factors need to be addressed and made available to enable an adequate environment. Above ground factors include the following:

1. Government policy/public opinion

- Positive government policy and legislation on unconventional resources, government stability;
- Coordination among government bodies;
- Upstream, midstream and downstream price regulation;
- Absence of anti-industry and anti-fracturing lobby; and public opposition to water impacts;
- Progressive fiscal regime and regulations;
- Extent of bureaucracy, ambiguity and ease of obtaining licenses.

2. Land access

- Minimal regulatory obstacles, and easy access to permits;
- Positive access terms, number of owners, and landholder incentives;
- Land footprint.

3. Business terms

- Political and macroeconomic stability;
- Attractive licensing, commercial and fiscal terms;
- Extent of environmental impact studies and delays in obtaining drilling permits;
- Social stability and security;
- Public and private sector involvement in mineral rights;
- Access to capital;
- Competitive environment, pricing and independent players.

4. Upstream supply chain/exploration and production industry structure

- Competitive industry structure (service, and exploration and production);
- Availability of capital.

5. Midstream

- Infrastructure availability and new build or access costs;
- Access to pipelines.

6. Water availability and management

- Water use and availability;
- Drilling and water discharge issues;
- Methane emissions.

V. CONCLUSIONS AND RECOMMENDATIONS

41. To date, shale oil and gas have been a success story in North America, but their development pace still needs to be confirmed over the coming years. However, the extent to which such experiences can be duplicated in other parts of the world is still uncertain and highly dependent on above ground and below ground factors, in particular water availability and use.

42. The different procedures applied to reduce the use of fresh water in fracking processes play a key role in the water-energy nexus by increasing water saving, especially in arid locations with significant shale oil and gas production potential. Many Arab countries, which rely on declining groundwater resources and desalinated water, are vulnerable to more frequent and severe impacts of water withdrawals, including withdrawals for hydraulic fracturing.

43. In addition, the chemicals used in the fracking process could pollute potable water. Fracking might also have other effects on the water sector due to the improper treatment and disposal of wastewater, contamination of the soil and environment caused by the chemicals injected into the liquids, and ground water pollution caused by leaks, flowbacks or spills.

44. In this context, policymakers should address the externalities involved, with the help of scientists and experts, to obtain the most reliable understanding of exploration and production activities and their effect on water quantity and quality, and compare the impact on water of conventional extraction techniques with unconventional methods.
